Physiological Cursor

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Abstract— **The objective of the project is to develop a physiological cursor using EMG sensors as an interface for computer human interaction, which results in the manipulation of a cursor on a computer screen. A physiological cursor will be able to assist people with disabilities that affect hand and arm movement and inhibit the usage of a standard mouse or touch pad interfaces. An array of electromyographic (EMG) sensors is used to monitor specific muscle movements. The filtered signals from the EMG sensors identify pre-specified gestures used to generate various mouse events: move (up, down, right, left), click (left click, right click), and drag-drop. This is input to a JAVA module, which executes the associated mouse event. The system can be customized to any individual through an auto-calibration routine that learns the physiological conditions of the user.**

I. Introduction

As computers become an integral part of human culture, people diagnosed with disabilities or specific diseases may find themselves physically incapable of performing standard computer operations. Due to physical restrains caused by these disabilities and diseases, a person may not be able to perform simple tasks with their arms and hands, such as moving a mouse or using a touch pad to manipulate the cursor on a computer screen. People who have suffered from a stroke or paralysis, have been diagnosed with Muscular Dystrophy, Multiple Sclerosis, Amyotrophic Lateral Sclerosis, Carpal Tunnel Syndrome, or Cerebral Palsy, would benefit from an alternative way to perform specific computer operations.

The objective of this project is to develop a physiological cursor, which results in the manipulation of a cursor on a computer screen. A physiological cursor will be able to benefit all of the different populations whose disabilities or diseases affect hand and arm movement. With each different disability or disease the Physiological Cursor will be able to adapt to the specific muscle groups that are not affected by the specific disorder and will allow the user to use those muscles to manipulate the mouse cursor on a computer screen.

The Physiological Cursor will be composed of a collection of electromyographic (EMG) sensors monitoring muscle movements, a hardware system for filtering and amplifying the signals, and a JAVA interface for cursor control. The hardware used is a modified version from a previous senior design project at TAMU (Spring 2005), which implemented an EMG-controlled robot. The JAVA module reads the outputted hardware data from the serial port and performs specific mouse functions accordingly, such as move right, left, up, down, and right and left click.

II. Background

Different products have been created to assist people who are diagnosed with disabilities or disorders that inhibit them from using a standard mouse or touch pad interfaces. Some products include:

1. *Head Movement Recognition*- Different head motion tracking mechanisms are NaturalPoint "SmartNav3", Madentec "Tracker One", Origin Instruments "HeadMouse Extreme", and Boost Technology "Tracer". These systems either use a reflective dot placed on the forehead or a helmet to track the movement of the head and relay up, down, left, and right cursor movements. To click, the SmartNav3 uses foot petals. The Boost "Tracer" and the "Tracker One" were designed to help people with disabilities, where the "SamrtNAV" was designed to increase productivity by being able to keep the hands on the keyboard. [1]
2. *Voice Recognition Systems*- Voice tracking systems allow spoken commands to manipulate a cursor. The first voice-activated mouse was Commodio's "Qpointer HandsFree". [2] Following the Qpointer was IBM's "Virtual Voice Mouse". [3]
3. *Eye-tracking Systems* - Eye tracking systems allow people to intact with the computer by simply moving their eyes. With a video-based system, the PC can tell precisely where the eyes are looking on the screen. An electrode interface measures the different electrochemical fields in the cellular fluid surrounding the eyes. When a person changes the position of their eyes different regions become either positively or negatively charged and a cursor will be moved on the screen accordingly. [4]

For each tracking and recognition product a specific set of muscles are needed for the manipulation of the cursor to be performed. Muscles in the neck will be used for head movement recognition, eye muscles for eye tracking, and the jaw and mouth muscles for speech recognition.

A product that is only built for a specific set of muscles limit the amount of people that will benefit from its use. Paraplegics will not be able to use a system that requires foot petals for clicking; people suffering from Myotonic Muscular Dystrophy will not be able to use the face muscles required for an eye-tracking system; people suffering from Amyotrophic Lateral Sclerosis may not be able to benefit from any of the products because the muscles affected from the disease are not predictable. To benefit every population multiple products would be required because each disability and disease either affects a very specific set of muscles or affects muscles at random.

The Physiological Cursor does not rely on a specific set of muscles and would be able to benefit every population through strategic placement of the EMG sensors on stronger sets of muscles. In each diagnosis, the Physiological Cursor would be able to provide a useful service to the affected person. Different products, other then the Physiological Cursor, can be used in each situation, but with the Physiological Cursor the EMG sensors can be adapted to each different disability and are able to adapt to each case according to the diagnosed needs.

III. Proposed Method

The Physiological Cursor project was designed to take the electrical signal from a contracting muscle and use that signal to manipulate the cursor on a computer screen. The Physiological Cursor research builds upon a previous senior design project, SEMGo, at Texas A&M University (Spring 2005), which implemented an EMG-controlled robot.

The Physiological Cursor project consisted of three parts:

1. Signal Acquisition and Muscle recognition
2. Analog to Digital Conversion and Signal Processing
3. Cursor Manipulation

Research concerning Signal Acquisition, Analog to Digital Conversion, and Signal Processing was previously conducted in the SEMGo project and was slightly adapted for the Physiological Cursor project.

A. Signal Acquisition and Muscle Recognition

An array of surface EMG sensors were used to monitor muscular contraction. When a muscle contracts a series of voltage changes are read by the EMG sensors on the surface of the skin.

EMG Sensors attached to forearm muscles

The system is calibrated to the user's unique physiological characteristics by having the user demonstrate a muscle flex pattern for the four cardinal directions and mouse click. The system is fully adaptable; it will accept any non-overlapping combination of muscle activation patterns for any direction. (The user can choose any pattern for any direction. As long as each direction has a unique pattern, the system will function properly.) For every direction a mean response is calculated. The distance of the input to the means is what determines what action the system should take.

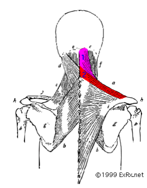
The Physiological Cursor was created to accommodate many different populations that would benefit from an alternative method for computer cursor movement. It was assumed that if a person were to benefit from a physiological cursor they were physically unable to use their arms or hands to control a standard mouse or touch pad. From this assumption research concerning alternative muscles to perform the needed movements for cursor manipulation was conducted. It was stipulated that muscles in the neck, face, and shoulder areas would provide the most natural movements. Three factors were reviewed in determining if a muscle should be used for a generic system:

1. Signal strength
2. User friendliness – the contraction of the muscle was not difficult to perform
3. Cursor standard – the movement to contract the muscle could be associated with standard cursor movements

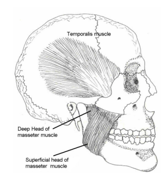
For basic manipulation of the cursor it was concluded that the upper shoulders (trapezius), the jaw (masseter), and the platysma neck muscle provided the best signals for the areas of muscles being researched.

BASIC MANIPULATION MUSCLES

Platysma [7]



Trapezius [5]



Masseter [6]

The Physiological Cursor's adaptability allows research to be conducted for each population that would benefit from its functionality. Populations include people who have suffered from a stroke or paralysis, have been diagnosed with Muscular Dystrophy, Multiple Sclerosis, Amyotrophic Lateral Sclerosis, Carpal Tunnel Syndrome, or Cerebral Palsy.

Right-Hemisphere Stroke- Right-Hemisphere Strokes result in the paralysis of the left side of the body and can also impair the ability to guide the capable hand. EMG sensors would be placed upper body muscles, such as the shoulders, neck, and face. [8]

Quadriplegia (affects 150,000 people in America)- Quadriplegia is the paralysis of the upper and lower body. EMG sensors would be placed on the face, specifically the forehead and the jaw muscles. [9]

Muscular Dystrophy (over 50,000 Americans diagnosed)- There are nine types of Muscular Dystrophy that can occur. The following five would directly benefit from a physiological cursor:

Myotonic affects the arms, legs, and face. The EMG sensors may be attached to the stomach, neck, shoulder, and back muscles.

Limb-girdle affects the shoulders. This may impair moving the arm to a position to interact with a cursor. The EMG sensors could be placed on the neck, face, and legs.

Distal affects the arms. The EMG sensors could be placed on the shoulders, neck, face, and legs.

Facioscapulohumeral affects the face, arms, and feet. The EMG sensors could be placed on the neck, shoulders, and legs.

Emery affects the shoulders and upper arms. The EMG sensors could be placed on the neck, face, and legs.[10]

Multiple Sclerosis (between 350,000 to 500,000 people currently diagnosed)- Multiple Sclerosis affects the brain and the spinal cord resulting in partial or mild paralysis, complete paralysis, loss of muscle tone causing stiffness (Spasticity, that restricts free movement of the affected limbs), slurred speech (Dysarthria), or muscle atrophy. When Multiple Sclerosis has affected the arms or shoulders the Physiological Cursor would benefit the person diagnosed. EMG sensors would be placed on the strongest muscles available in each different case of Multiple Sclerosis. [11]

*Amyotrophic Lateral Sclerosis (*over 20,000 Americans currently diagnosed, 5,000 diagnosed each year)- Amyotrophic Lateral Sclerosis attacks the nerves responsible for controlling voluntary muscles. EMG sensors could be placed on the stronger muscles when the arms or shoulders are weakened. The EMG sensors may have to be continually moved due to continued weakening of the muscles. [12]

Carpal Tunnel Syndrome (affects one out of every one hundred people)- Carpal Tunnel Syndrome affects mobility due to extreme pain in the wrist. EMG sensors would be placed on the shoulders, neck, face, or lower body. [13]

Cerebral palsy (500,000 Americans diagnosed) – Cerebral palsy results from brain injury or abnormal brain development. [14] There are four types of cerebral palsy: Spastic, Nonspasic, Mixed, and Total body cerebral palsy.

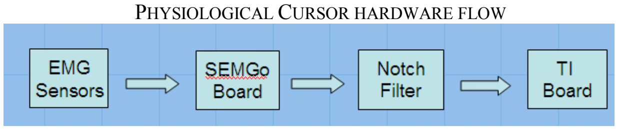
Spastic cerebral palsy - EMG sensors would have to be placed on the forehead and neck. [15]

Triplegia Spastic cerebral palsy- EMG sensors would be placed on the face, legs (accordingly), neck, and shoulders.[16]

B. *Analog to Digital Conversion and Signal Processing*

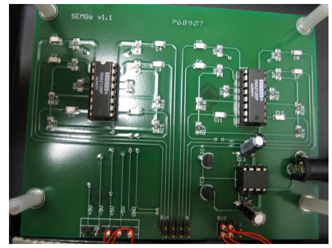
After the signal collected from the EMG sensors, it is filtered through the improved SEMGo hardware.

PHYSIOLOGICAL CURSOR HARDWARE FLOW



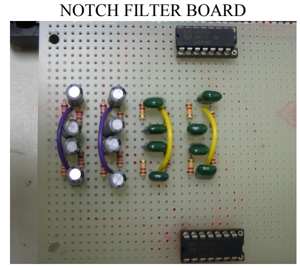
SEMGo v1.1 BOARD: This board is comprised of four main parts, a pre-amp filter, an amplifier, a filter with voltage biasing, and power circuitry. The system was designed to be portable and therefore needed to be powered from batteries. The power circuitry on this board is to supply multiple voltages to multiple boards from a single 9V source. The EMG signal is first passed through a pre amp filter. This is a high pass filter with a frequency of 70Hz. The purpose of this filter is to help remove DC bias and reduce noise. The signal is then amplified with a gain of approximately 1000V/V. After amplification the signal is sent through another high pass filter to help stabilize the signal. Also, the signal is adjusted so that it is biased to 1.5V instead of 0V. [17]

SEMGO V1.1 BOARD



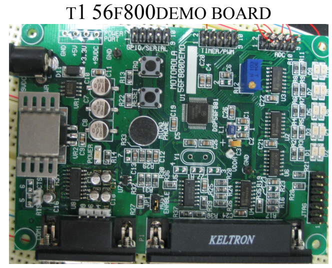
NOTCH FILTER BOARD: This is a four channel notch filter board. Its only purpose is to filter out noise at 60Hz caused by AC power. At the output of this board there is a 40dB attenuation of 60Hz in the EMG signal. This keeps the noise at 60Hz from dominating the signal, and increases the signal to noise ratio.

NOTCH FILTER BOARD



TI 56F800DEMO BOARD: This board contains a Digital Signal Processor (DSP) made by Ti. The analog EMG signal is digitized and then analyzed by the DSP. A Fast Fourier Transform (FFT) is computed and compared to the data collected at calibration time. The DSP decides what action to take and sends the command to the PC over the serial port.

T1 56F800DEMO BOARD

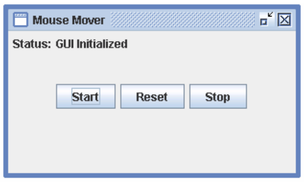


C. *Cursor Manipulation*

When a user of the Physiological Cursor flexes one of the calibrated muscles, the computer screen cursor performs the specific action associated with that particular movement. These actions include move (up, down, right, left), click (left click, right click), and drag-drop. To manipulate the cursor according to the specific actions a Java interface was created.

The Java interface was implemented including a GUI to allow the user to begin, stop, and restart the cursor movement. When the Java interface is initiated, the computer screen cursor is placed in the middle of the screen based on the screens dimensions. These dimensions are used to insure that the cursor is never moved off the screen in either the x or y direction.

PHYSIOLOGICAL CURSOR GUI



After the muscle signal is processed, a packet of bytes, serial packet, is sent to the Java interface through the serial port. This packet contains a series of bits that encode the x and y direction of the cursor movement and a value for the left and right click functions.

PHYSIOLOGICAL CURSOR SERIAL PACKETS

	Binary	*Hex*
Left	01000011 00111110 00000000	43 3E 00
Right	01000000 00000010 00000000	40 02 00
Up	01000000 00000000 00000010	40 00 02
Down	01001100 00000000 00111110	4C 00 3E

As each of the user's movements send the corresponding serial packet over the serial port, the Java interface receives each byte and individually checks if it is the first byte in a serial packet series. In a complete serial packet the first byte would have the 6th bit as a 1, and the second and third bytes would have their 6th bit as a zero. If this is the case then the bytes are manipulated to create values for the left click bit, right click bit, x-direction byte, and y-direction byte.

SERIAL MOUSE BYTES PACKET

```
      1st byte        2nd byte         3rd byte
          ================  ===============  ================
           - 1 ? ? Y Y X X  - 0 X X X X X X  - 0 Y Y Y Y Y Y
          ================  ===============  ================
               | | \ / \ /      \---------/      \---------/
               | |  |   |            |                |
               | |  |   \----\       |                |
               | |  \--------|-------|--------\       |
               | |          / \ /---------\  / \ /---------\
               | |         ================ =================
               | |          0 0 0 0 0 0 0 0  0 0 0 0 0 0 0 0
 Left Button --/ |         ================ =================
Right Button ----/            X increment      Y increment
                                                                [14]
```

These values are then used to move the cursor or instantiate a click through the Java Robot class. The Robot class uses the functions mousePress, mouseRelease, and mouseMove to manipulate the cursor on the screen.

IV. RESULTS

After completing all of the different aspects of the Physiological Cursor project, the project was thoroughly tested to insure proper functionality. Each action to be performed by the cursor was successfully demonstrated on the computer screen. These actions included move (up, down, right, left), click (left click, right click), and drag-drop. Due to user control, the cursor was found to move faster then anticipated due to elongated muscle contraction time. With different calibration techniques the user may have found the specific muscle movements to be more precise and reliable for the computer screen cursor movements.

Further testing was completed through implementing the Physiological Cursor with a standard Serial Mouse as input instead of the EMG sensors. The Serial Mouse sent the same serial packet protocol to manipulate the cursor over the serial port to be read by the Java interface. When tested all of the functionality was working, including drag-drop, highlighting text and multiple objects, and double clicking. The actions performed by the Serial Mouse were more precise and controlled. This control was due to the fact that the Serial Mouse was able to send more serial packets in a shorter amount of time compared to the EMG sensors, so the cursors response on the screen was better.

The serial packets sent from the Physiological Cursor hardware were the same serial packets that the serial mouse sent to perform the different actions. With the Physiological Cursor hardware, the serial packet data was hard coded within case statements, so once it was determined that a specific movement was performed then each time the same serial packet was sent to result in the action associated with that movement. With each movement the cursor was moved two pixels. The smaller amount of pixels resulted in more precise control of the cursor.

V. CONCLUSION

All muscles can produce electromyographic signals that can be used as input into the Physiological Cursor. Muscle versatility and an accurate operational product, such as the Physiological Cursor, allows multiple populations to adjust the EMG sensors to their unaffected muscles and correctly move the cursor on the computer screen. This adaptability means that the Physiological Cursor is not specific to helping only a specific population, but can benefit multiple populations simultaneously unlike the current products available for cursor manipulation.

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